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EFFECTIVENESS OF A USDA-DEVELOPED MIDDLE FLAMER ON BOLL WEEVIL DESTRUCTION INSIDE COTTON SQUARES[1]

R. E. Parker, E. C. Burt, F. E. Fulgham[2], and M. E. Merkl[3]

INTRODUCTION

The boll weevil, Anthonomus grandis Boheman, has been the major pest of cotton since entering the United States from Mexico in 1892.[4] It now inhabits practically all cotton producing areas of the United States with the exception of certain areas of West and Northwest Texas, New Mexico, Arizona, Nevada, and California.[5] The adult weevil has jaws at the end of its snout and by means of these it causes damage to cotton by eating into squares and bolls.

The adult female weevils lay eggs in cavities eaten into the squares and young bolls. Squares containing eggs or feeding punctures usually fall to the ground 6 or 7 days after being punctured, but the small bolls usually remain on the plant. The eggs hatch in 3 or 4 days into very small white larvae, which feed 7 to 12 days inside the square or boll. The larvae then pupate and in 3 to 5 days become adults.[6] Thus the time from egg deposition to adult emergence ranges from 13 to 21 days and the infested square is on the ground from 1 to 2 weeks during this period.

1/ The research was accomplished as a cooperative investigation between the Agricultural Engineering and Entomology Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the Delta Branch, Mississippi Agricultural Experiment Station, and is a contribution to Regional Cotton Mechanization Project S-2.

2/ Agricultural engineers, Agricultural Engineering Research Division, U.S. Department of Agriculture, located at State College and Stoneville, Miss.

3/ Entomologist, Entomology Research Division, Agricultural Research Service, U.S. Department of Agriculture, located at State College, Miss.

4/ Andrews, W. B. Cotton production, marketing, and utilization. 476 pp., illus. State College, Miss. 1950.

5/ Anon. 15th annual conference report on cotton insect research and control. Memphis, Tenn. Jan. 9-10, 1962.

6/ Fenton, F. A., and Dunnam, E. W. Biology of the cotton boll weevil at Florence, S.C. U.S. Dept. Agr. Tech. Bul. 112, 1929.

Boll weevils are currently being controlled by various insecticides. However, recent attempts have been made by Burt and others[7/] to destroy mechanically weevils inside squares and bolls that had fallen to the ground. The infested squares were picked from the ground and cracked or crushed by a modified version of a flail-type harvester. The experimental machine picked up 80 to 95 percent of all squares on the ground. An overall evaluation of the machine and the beneficial effects of killing weevils inside squares is incomplete.

FLAME INVESTIGATIONS ON WEEVIL DESTRUCTION

This is a progress report on the research in destroying young boll weevils in squares on the ground by use of heat. Heat is already used in flame cultivation to control weeds in cotton. This is the first known attempt to develop a flame burner for the two-fold purpose of controlling weeds and at the same time killing immature stages of the boll weevil inside fallen squares.

Materials and Methods

Because of its efficiency, A USDA-developed hooded burner (fig. 1) was

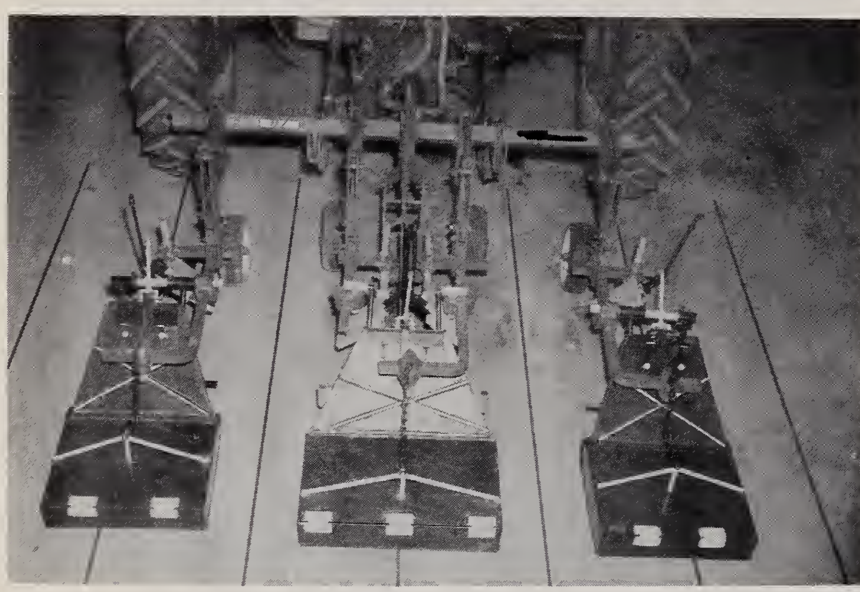

Figure 1. A 2-row unit equipped with Stoneville Hooded burners used to control weeds by flaming middles of cotton rows. Lines between burners represent the centers of rows spaced 40 inches apart.

used in this study.[8/] The burner had previously been used only for weed-control research. Because the hood slides on the soil surface and has a flap attached to its trailing edge, this particular burner is capable of holding heat much longer than a conventional burner.

7/ Burt, E. C., Davich, T. B., Merkl, M. E., and Cleveland, T. C. Mechanical destruction of fallen boll weevil infested cotton squares. Amer. Soc. Agr. Engin., SE Sec. Proc., Atlanta, Ga. Feb. 4, 1964.

8/ Parker, R. E., and Holstun, J. T. New developments in flame cultivation. Amer. Soc. Agr. Engin., SE Sec. Proc. Feb. 1963.

The hooded burner does a satisfactory job of controlling weeds in middles at a fuel cost of 20 to 40 cents per acre per application. Applications are required about once a week. No previous attempt has been made to evaluate the performance of the burner when used for insect control, although it was believed that some crawling insects were being killed when passed over by the burner in weed-control studies. The ultimate is the technique of flaming the middles of row crops that would serve a two-fold purpose--weed control and partial insect control.

The effectiveness of the center burner, shown in figure 1, in killing boll weevils inside cotton squares was evaluated by passing it over lots of 100 squares each at speeds of 1/4, 1/2, 1, and 1-1/2 miles per hour. The squares, only partly infested with weevils, were spread on the soil directly behind the front wheels of a tractor (fig. 2) to avoid their being crushed

Figure 2. One hundred cotton squares partly infested with boll weevils laid on the ground for flame treatment. Squares were placed behind front tractor wheels so that middle burner would flame uncrushed squares.

before the burner passed over them. This procedure was repeated four times. The results were then compared with those obtained from 4 lots of 100 squares each, which had not been flamed.

Each lot of 100 squares was then placed in half-gallon ice cream cartons covered by screen wire lids. Weevils that had crawled to the lid were removed from the cartons daily. Daily counts were discontinued 14 days after the squares were flamed. Theoretically, this was sufficient time for all larvae

to reach adulthood. However, later tests showed that weevils continued to emerge from the squares beyond the 14-day period. This indicates that some of the squares picked from the ground were infested with weevils that were still in the egg stage. These squares undoubtedly had been knocked off the cotton plants either by man, animal, machine, or adverse weather. (The squares used for the first test were collected one day after a heavy rain.)

Temperature-time relationships were recorded by use of a millivolt recorder (Fig. 3). Temperature was obtained by inserting a copper-constantan

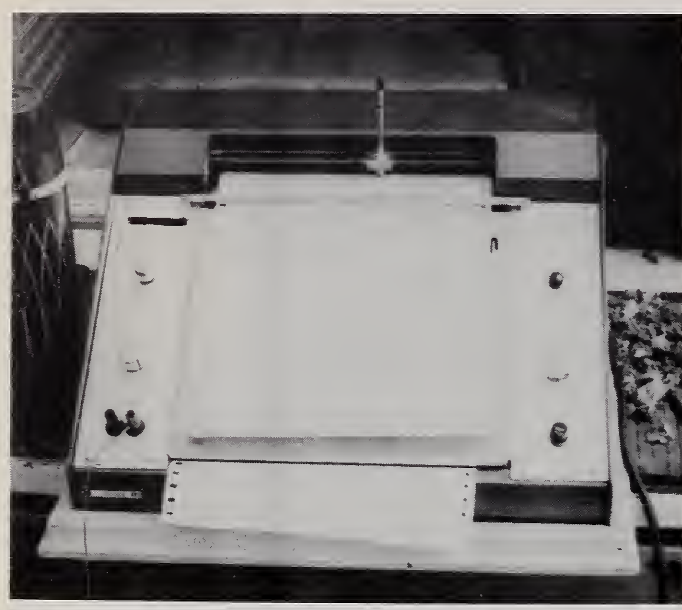

Figure 3. Millivolt recorder employed to measure temperatures inside cotton squares as the hooded burner passed over them.

thermocouple inside a cotton square and passing the hooded burner over the square at the same speeds employed in the large test. This procedure was repeated several times to get a rough estimate of the temperatures to which the young weevils were being exposed.

Based upon the erratic results of the first test, it was concluded that the procedure should be repeated using a burner with a longer hood. In addition, to verify the results of the first test, the original (standard-hood) burner was tested again.

Burner Modifications

The 16-inch hood of the original burner was extended 18 inches in an effort to increase the efficiency of the burner. The only limitation on the maximum length of the hood is the practicability of transporting the burner by a tractor. However, the burner with a 34-inch hood shown in figure 4 was easily transportable. This extended-hood burner is shown in figure 5 passing over a specific lot of 100 cotton squares. Temperatures inside squares were recorded when the extended-hood burner was used.

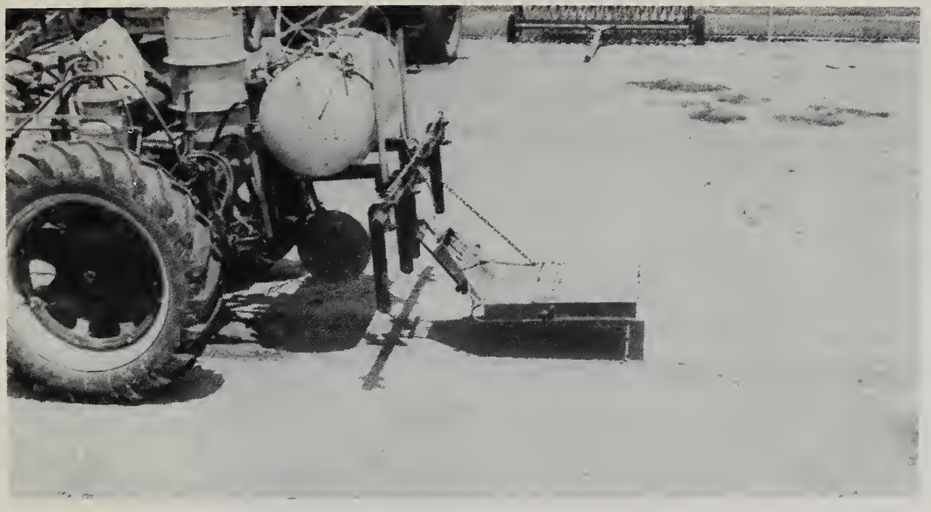

Figure 4. The 16-inch Stoneville hooded burner with an 18-inch hood extension. This burner could be easily transported.

Figure 5. Burner with hood 34 inches long passing over cotton squares. The 18-inch extension was bolted to the original 16-inch hood after rear flap had been removed.

In an attempt to further increase the effectiveness of heat in this method of boll weevil control, two burners each with 34-inch hoods were mounted in series or in tandem (Fig. 6). The frame for transporting this burner arrangement has not been satisfactorily developed, but there appears to be no reason why a satisfactory frame could not be designed.

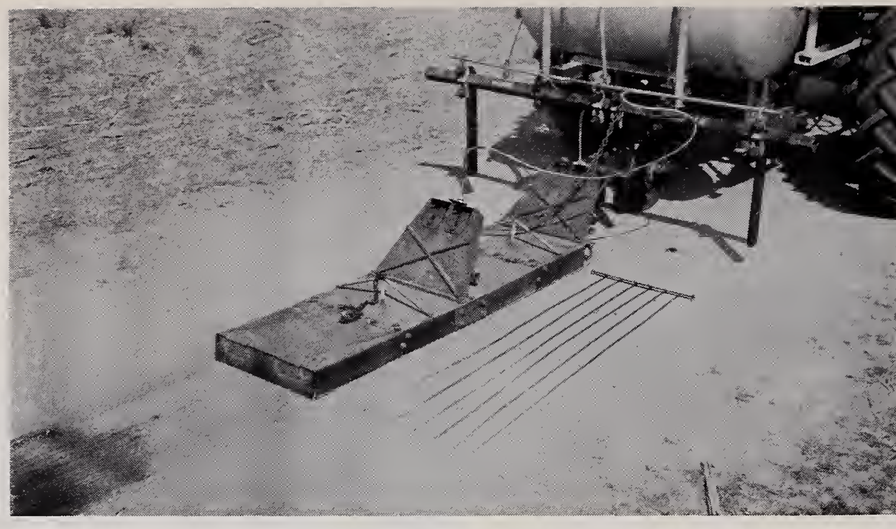

Figure 6. Two extended-hood middle burners mounted in tandem. The total hood length is 68 inches.

Lengths of sash chain were used in an attempt to turn the squares while the burner was over them. It seems practicable to assume that a square that is turned while being flamed would reach a higher inner temperature than a square that stays in one position. This assumption was based primarily on the desirability of obtaining an isothermal condition inside the square and of exposing the square to heat for the maximum length of time.

Results of Flaming Squares

The average number of weevils that emerged from 100 cotton squares 14 days after the squares had been flamed at various speeds is shown in the following tabulation. All squares were flamed with the standard-hood burner (equipped with a 16-inch hood) and operated at 60 p.s.i.g., at Stoneville, Miss., July 11, 1963.

	Weevils that emerged per 100 cotton squares
	Number 1/
Not flamed, check	20.25 a
Flamed at burner speed of:	
0.25 m.p.h.	7.50 b
0.50 m.p.h.	15.75 ab
1.00 m.p.h.	18.25 a
1.50 m.p.h.	18.75 a

1/ Values are averages based on weevil emergence from four lots of 100 squares each. Any two means not followed by a common letter are different at the 5-percent level or probability.

Flaming at the slowest speed (1/4 m.p.h.) effectively reduced the number of weevils that emerged. Weevils that emerged after the squares were flamed tended to increase as the speed of flaming increased up to a speed of 1 mile per hour. Flaming at speeds higher than 1 mile per hour had little effect on increasing weevil emergence.

Based upon the initial results shown in the foregoing tabulation, it was concluded that boll weevils inside cotton squares could be effectively controlled by flaming the squares after they drop to the ground. Weevil population can be reduced approximately two-thirds by flaming squares with the standard-hood burner traveling at a speed of 1/4 mile per hour. However, it was further concluded that a speed of 1/4 mile per hour was not practical on a large-scale field operation. Therefore, an 18-inch hood extension was attached to the hood of a burner equipped with a 16-inch hood (a standard hood) in an attempt to increase the efficiency of the burner and the speed of operation.

The performance of the burner equipped with a 34-inch hood was evaluated in the same manner as that of the standard-hood burner. The major difference in test procedure was that the cotton squares had been extracted from a different population for the extended-hood burner tests. The results of flaming squares with the extended-hood burner are shown in table 1 together with results from a "rerun" with the standard-hood burner.

It was apparent that the efficiency of the hooded burner was greatly increased by attaching a hood extension on the standard-hood burner. Moreover, about the same effectiveness percentagewise was achieved with the extended-hood burner traveling at 0.50 m.p.h. as was achieved with the standard-hood burner traveling at 0.25 m.p.h. when both runs with the standard-hood burner are considered.

Passing the extended-hood burner at 0.25 m.p.h. over infested cotton squares killed almost all weevils inside the squares. Because there was such a large difference in weevil emergence from squares that had been flamed at 0.25 and 0.50 m.p.h., it is possible that a critical temperature was achieved inside most squares while they were flamed at 0.25 m.p.h. with the extended-hood burner. It may be theorized that lethal temperatures of boll weevils depend upon the boll weevil's stage of development.

Table 1. Boll weevil emergence from squares flamed at stated speeds with standard-hood and extended-hood burners, August 2, 1963, Stoneville, Miss.
[Burners were operated at 60 p.s.i.g. fuel line pressure]

Burner	Weevils that emerged from squares not flamed-check	Weevils that emerged from squares flamed at[1/]			
		0.25 m.p.h.	0.50 m.p.h.	1.00 m.p.h.	1.50 m.p.h.
	Number	Number	Number	Number	Number
Standard-hood--	44.25 a	20.00 b	22.75 b	39.25 a	[2/]
Extended-hood--	74.50 a	4.25 e	41.75 d	57.25 c	66.50 b

1/ Values are based on average weevil emergence from four lots of 90 squares each flamed by the standard-hood burner and from four lots of 100 squares each flamed by the extended-hood burner. Any two means for a particular burner not followed by a common letter are different at the 5-percent level of probability.

2/ It was deemed unnecessary to flame again at 1.50 m.p.h. with the standard-hood burner.

Such a theory is supported in part by the daily weevil counts from the extended-hood burner treatments shown in table 2. A substantial number of weevils did not emerge from squares flamed at 0.25 m.p.h. until 10 days after flaming. On the other extreme, substantial weevil emergence was recorded for the check and the 1.5 m.p.h. treatment only 7 days after the field test. Since the weevils that survived the 0.25 m.p.h. treatment did not emerge from the squares until 10 to 12 days after flaming, it may be safely assumed that these weevils were either eggs or larvae at the time the squares were flamed. It may therefore be deducted that boll weevils can withstand more heat when they are either in the egg or young grub stage of development than when they are in the older grub or pupa stage of development.

Another and more practical explanation of the trends shown in table 2 is that weevils in their latter days of development had already eaten most of the food inside the cotton square and, consequently, were subjected to more intense heat than the eggs or young grubs. It is clearly recognized that a "hollow" cotton square or young boll is more easily heated throughout than is a "solid" square or young boll. Temperature measurements tended to support this explanation.

The performance of two extended-hood burners mounted in series (tandem) was evaluated by the same method as was used in evaluating the effectiveness of the standard-hood and extended-hood burners. Results of these tests are shown in table 3.

Because the effective speed of one extended-hood burner is approximately twice that of one standard-hood burner, it may be theorized that the effective speed for two extended-hood burners mounted in tandem (fig. 6) would be four times greater than that of one standard-hood burner. Tests showed this theory to be approximately correct because the effective speed for the extended-hood burners mounted in tandem was around 1 m.p.h. The difference in number of boll weevils that emerged from squares treated at 1 and 2 m.p.h. indicates that the critical effective speed is somewhat greater than 1 m.p.h.

The effectiveness of two extended-hood burners mounted in series (tandem) was decreased by the use of the drag chains. During tests the drag chain arrangement had a tendency to pile loose soil on the squares; this possibly provided some insulation to the squares.

Table 2. Weevils emerging daily from 400 squares after they were flamed at various speeds by the extended-hood Stoneville burner, August 2, 1963

Days after flaming	Weevils that emerged from squares not flamed-check	Weevils that emerged from squares flamed at- 0.25 m.p.h.	0.50 m.p.h.	1.00 m.p.h.	1.50 m.p.h.
	Number	Number	Number	Number	Number
4	0	0	0	0	1
5	0	0	0	0	1
6	2	0	0	0	3
7	23	0	4	9	20
8	1/	1/	1/	1/	1/
9	104	0	38	53	86
10	90	5	57	97	81
11	52	6	47	49	45
12	15	3	4	9	10
13	2	0	4	1	3
14	4	1	0	1	1
28 2/	5	2	11	10	15

1/ No count made on eighth day.
2/ Dead adult weevils were counted 2 weeks after the 14-day count.

Table 3. Boll weevil emergence from squares flamed with two extended-hood burners mounted in tandem with and without drag chains, October 7, 1963, Stoneville, Miss.

Burner arrangement 1/	Weevils that emerged from squares not flamed-check	Weevils that emerged from squares flamed at 2/			
		0.5 m.p.h.	1 m.p.h.	2 m.p.h.	3 m.p.h.
	Number	Number	Number	Number	Number
Two extended-hood burners mounted in tandem:					
Without drag chains	13.75 a	0.00 b	0.75 b	8.75 ab	10.50 ab
With drag chains	15.25 a	.25 b	4.50 b	15.25 a	19.75 a

1/ Squares flamed by each of these burners were extracted from a different population.

2/ Values are based on average weevil emergence from four lots of 100 squares. Any two means for a particular burner arrangement not followed by a common letter are different at the 5-percent probability level.

Temperatures measured inside the cotton squares were generally inconsistent because of the wide variability in square size and density. Recordings as the standard-hood burner passed over a bare thermocouple at different speeds showed that air temperatures under the hood during the hottest 5-second period were as follows:

	Air temperature °F.
0.25 m.p.h.	Over 750°
1.00 m.p.h.	345° to 575°
2.00 m.p.h.	305° to 480°
3.00 m.p.h.	240° to 330°

Temperatures inside the squares rose insignificantly above that of the atmosphere when the standard-hood burner passed over squares at speeds of over 1 m.p.h. At 1 m.p.h., temperatures inside the squares reached a maximum of only 106° F.; while at 0.25 m.p.h., temperatures reached a maximum of approximately 175° F. Squares having approximately the same characteristics - green, uninfested, and about three-eighths of an inch in diameter - were selected for these measurements. Temperatures inside squares containing well-developed larvae rose approximately 30° F. higher than they did for squares described previously. Initial temperatures of all squares was 85° F.

CONCLUSIONS

The following conclusions resulted from the tests described:

1. Young boll weevils inside fallen cotton squares can be destroyed by heat.

2. The standard Stoneville hooded burner will produce enough heat to destroy weevils inside cotton squares. However, the speed of travel required for the standard-hood burner to effectively destroy the weevils is too slow to be practical.

3. Increasing the length of the burner hood by 18 inches (to 34 inches) approximately doubled the effectiveness of the burner. However, the necessary speed of travel is still too slow to recommend such an arrangement as a commercial practice.

4. Mounting two extended-hood burners in series (tandem) approximately doubled the effectiveness of one extended-hood burner. However, the effective speed is still impractical.

It is evident that if boll weevils are to be economically destroyed by subjecting them to intense heat, further research and development are essential. Information on (1) temperature and exposure time related to weevil kill, and (2) thermal properties of infested cotton squares, is needed before a heat-producing device can be designed efficiently to meet the requirements.